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TECHNICAL REPORT BRL-TR-2840

IGNITION DIAGNOSTICS OF THE 120-mm XM859-MP CARTRIDGE

LANG-MANN CHANG

AUGUST 1987

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The ignition processes occurring in the XM859 High-Explosive Anti-Tank Multi-Purpose (HEAT-MP) cartridge were investigated via simulator diagnostics. The pressure behavior and flamespreading in the simulator chamber, intruded by the complex afterbody of the XM859 projectile, were analyzed in detail. The rounds fired in the study were packed with M30 propellant in two bed configurations: all granular and granular plus slotted stick. Their results were compared. Temperature effects on the ignition processes for these rounds conditioned to 241°K (-32°C) and 228°K (-45°C) were also examined. The results show that the rounds with a slotted stick propellant bed have achieved more effective ignition and their ignition processes are less sensitive to temperature variation from ambient to cold. In all of the cases studied, there was no sign of forming adverse pressure waves at 17 MPa or less which could lead to catastrophic overpressurization in cold temperature environments.

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due to poor ignition and flamespreading. The obturator on one of the rounds conditioned to 241°K (-32°C) and all of the rounds conditioned to 228°K (-45°C) were found to have severe cracks in the circumferential direction.

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I. INTRODUCTION

The AAI Corporation, Baltimore, Maryland, was awarded a contract by the Army for the advanced Development of the XM859 HEAT-MP tank ammunition which would ultimately replace the standard M831 HEAT round. The new ammunition would provide improved performance and effectiveness to defeat increasing threat armor and soft targets. The XM859 projectile has a low drag shape with folding fins which intrude significantly into the gun chamber, see Figure 1. The complex afterbody of the projectile severely limits the length of the ignition system as well as impedes the flamespreading in the propellant bed. As a result, catastrophic pressure waves leading to a breech blow could develop if the ignition system and the propelling charge are not properly

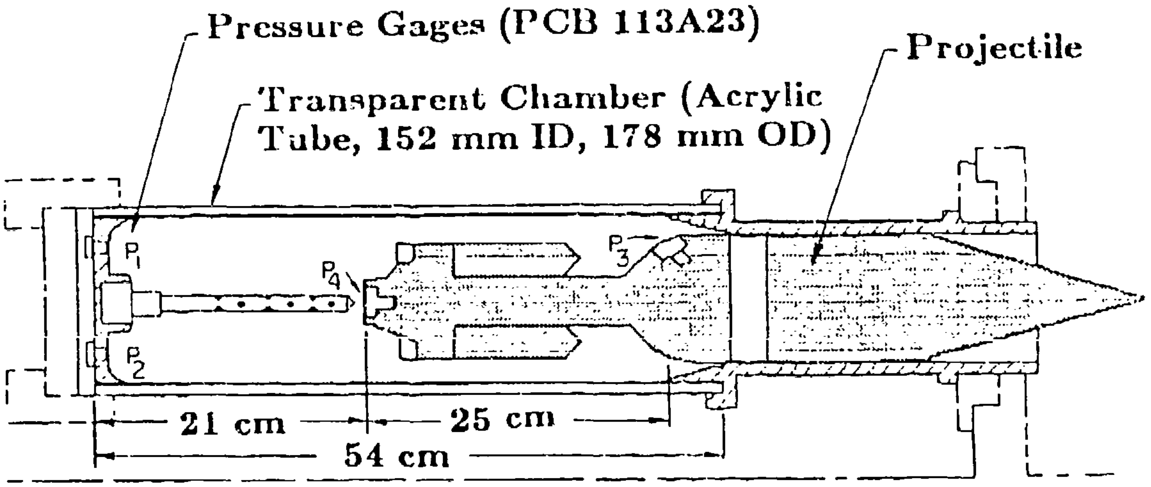

Figure 1 Cross-Sectional View of 120-mm Gun Simulator

designed, especially when fired at cold temperatures. Due to this concern, the AAI Corporation requested the Ballistic Research Laboratory (BRL) to conduct the subject study before proceeding to their gun firing tests on cold rounds to ensure that there was no such a potential hazard developing in the early phase of the ignition process.

The study was conducted via diagnostics in a cartridge simulator. This technique has been used extensively at the BRL[1,2] in support of the

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[1]L.M. Chang and J.J. Rocchio,"Early Phase Interior Ballistic Cycle Studies in a 105-mm Tank Gun Simulator," Proceedings of the 8th International Symposium on Ballistics, pp. I-13 - I-24, Oct 1984.

[2]A.W. Horst and T.C. Minor,"Theoretical and Experimental Investigation of Flamespreading Process in Combustible-cased, Stick Propellant Charges," Proceedings of 8th International Ballistics Symposium on Ballistics,pp. IB-21 - IB-31, Oct 1984.

development of various advanced HEAT and KE rounds. It can provide insights into the functioning of the igniter, flamespreading, and formation of pressure waves in the gun chamber. In addition, an early failure of the obturator during the engraving stage can be detected.

In this study, all of the rounds fired in the simulator were packed with M30 propellant. Two kinds of propellant bed configurations were involved: all granular and granular plus slotted stick, as schematically shown in Figure 2. The latter configuration consisted of a granular propellant bed in the rear section of the simulator chamber and a slotted stick propellant bed in the forward section around the afterbody of the projectile. The advantages of using a stick propellant charge have been discussed extensively.[2-5] The stick propellant charge was designed to provide low-resistance flow channels for the gases, generated by the primer and the propellant combustion around the primer, to quickly transport to the forward section of the propelling charge. In the present report, the pressure data and photographic evidences of flamespreading for these bed configurations were compared. Temperature effects on the ignition process in the rounds conditioned to 241°K (-32°C) and 228°K (-45°C) were examined.

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[3] Thomas C. Minor, "Mitigation of Ignition-Induced, Two-Phase Flow Dynamics in Guns Through the Use of Stick Propellants," ARBRL-TR-02508, Ballistic Research Laboratory, USA ARRADCOM, Aug 1983.

[4] Thomas C. Minor and Albert W. Horst, "Ignition Phenomena in Developmental, Stick Propellant, Combustible-Cased, 155-mm, M203E2 Propellant Charges," ARBRL-TR-02568, Ballistic Research Laboratory, USA ARRADCOM, Jul 1984.

[5] Albert W. Horst, Frederick W. Robbins, and Paul S. Gough, "Multidimensional, Multiphase Flow Analysis of Flamespreading in a Stick Propellant Charge," ARBRL-MR-03372, Ballistic Research Laboratory, USA ARRADCOM, Aug 1984.

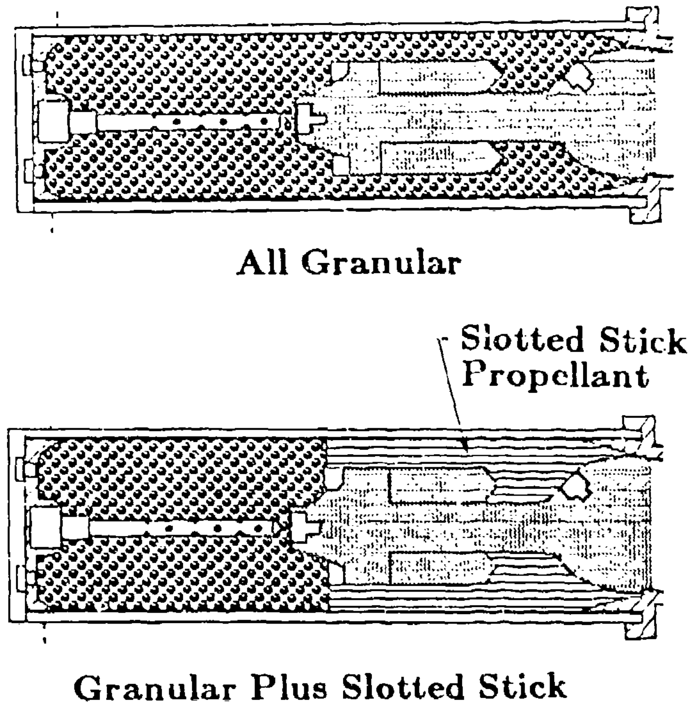


Figure 2. Propellant Bed Configurations

II. EXPERIMENTAL SETUP

Figure 1 depicts a cross-sectional view of the 120-mm tank gun simulator assembly. The simulator chamber, which closely resembled the geometry and dimensions of the gun chamber, was made from a transparent cast acrylic tube with inside and outside diameters of 152 mm and 178 mm, respectively. It offered excellent optical visualization for the recording of the flamespread taking place inside. The chamber was capable of withstanding dynamic pressures in excess of 12 MPa before it ruptured. The forward part of the simulator, in which an inert XM859 projectile resided, was cut from an actual gun tube. Via proper adapters the two ends of the simulator were firmly mounted on a steel fixture.

Four pressure gages (PCB Series 113A23, effective pressure measurement up to 69 MPa) were installed for chamber pressure measurements: two (P_1 and P_2) in the breech end, one (P_3) in front of the fin assembly, and one (P_4) in the boom end of the projectile. For recording the flamespreading along the chamber length, two high-speed 16-mm cameras were used. The cameras were set at a framing rate of 6,000 pictures per second. A firing fiducial (time at which the firing voltage is applied to the igniter) was placed on the film to aid in correlation of the film data with other measurements recorded during the experiments. A Schaevitz Linear Variable Differential Transformer (LVDT, Model No. 2000HR) was used for the recording of the projectile motion as a function of time. The LVDT is an electromechanical device that produces an electrical output proportional to the displacement of a separate movable core. In the present application, the core was attached to the projectile nose.

As shown in Figure 1, the inert XM859 projectile consisted of a rear boom with six-bladed folding fins, cylindrical body, and conical nose. The chamber in each round was fully packed without apparent ullage and the primer used was a short bayonet-type XM123E1 electric primer with benite as the igniter material.

Figure 3 illustrates the experimental arrangement for the simulator diagnostics. The fire control, data acquisition, and data reduction were performed by using the Ballistic Data Acquisition System (BALDAS) at the BRL.

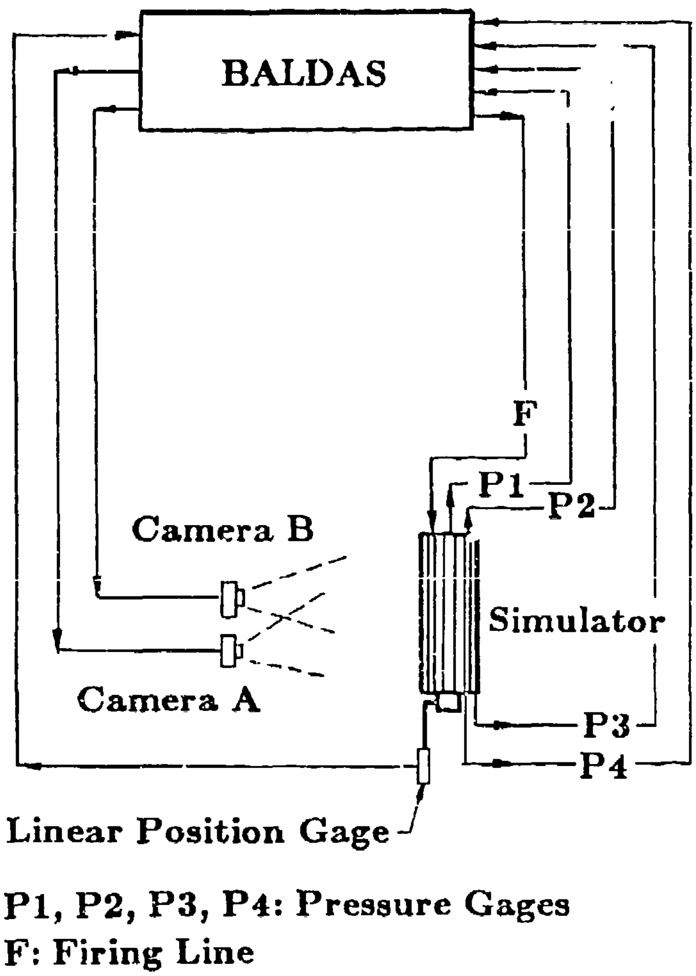


Figure 3. Experimental Setup

III. RESULTS AND DISCUSSIONS

In the present investigation, eleven rounds including inert and live propellants were fired at three temperature conditions (ambient, 241°K {-32°}, and 228°K {-45°C}) as listed in Table 1. In most cases, two rounds packed in the same fashion were fired to check the reproducibility of measured data. The results obtained are presented and analyzed in the following sections.

Table 1. Simulator Diagnostics of XM859 HEAT-MP Cartridge

Rd No.	Charge	Temp. °K (°C)	Obturator	Ig. Delay (ms)
1	gran. (inert)	amb.	good	
2	gran. (inert)	amb.	good	
3	gran.	amb.	good	7.2
4	gran.	amb.	good	6.9
5	gran. + stick	amb.	good	4.9
6	gran. + stick + case	amb.	good	4.6
7	gran. + stick + case	228 (-45)	cracked	14.1
8	gran. + case	228 (-45)	cracked	11.1
9	gran. + stick + case	228 (-45)	cracked	11.9
10	gran. + stick + case	241 (-32)	good	12.5
11	gran. + stick + case	241 (-32)	cracked	6.4

Note: Ig. = ignition
gran. = granular
stick = slotted stick
case = combustible cartridge case
amb. = ambient, i.e., around 294°K (21°C)

A. Inert Propellant

Round No. 1 and Round No. 2 were fired with a granular inert propellant bed at ambient temperature. The grain size of the inert propellant was 28.5 mm by 12.7 mm (length by diameter) with 7 perforations. The tests were to determine the pressure rise in the propellant bed as a result of ignition of a primer alone. Also examined were the flow characteristics through the propellant bed and the flamespreading in the bed. Figure 4 exhibits the pressure data recorded, showing that the maximum chamber pressure attained in the ignition process was approximately 0.5 MPa. This pressure value would vary slightly as a function of a number of variables, such as the total output of the igniter, loading density of the chamber, etc. The pressure P_4 responded earlier than P_1 and P_2 because the P_4 gage was located closer to the vent holes of the primer as seen in Figure 1. The pressure rise P_3 at the forward end of the chamber lagged the breech pressure by approximately 1 ms. Apparently, the igniter gases experienced a significant flow resistance in the

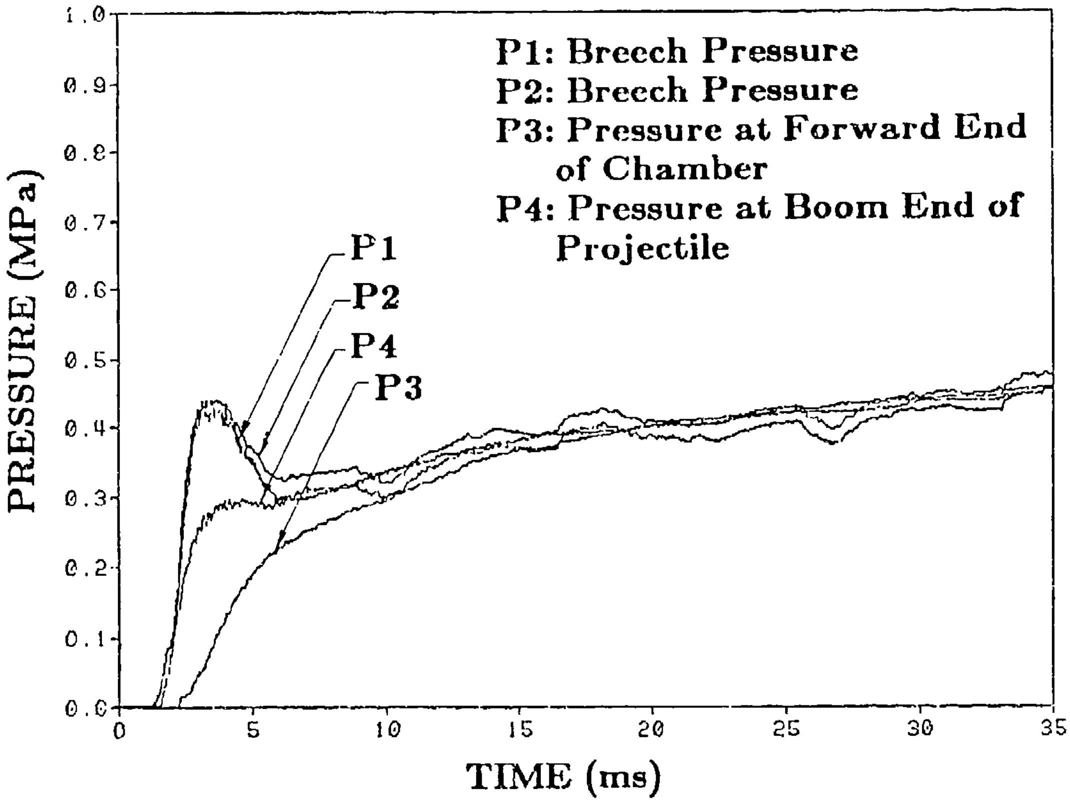


Figure 4. Pressure-Time Data (Inert Propellant Packed Chamber, Fired at Ambient Temperature)

propellant bed. We also note that there is a peak along P_1, P_2, and P_4 curves, occurring at approximately 3.8 ms after application of the firing voltage. The occurrence of these peaks is believed to be associated with the change from choked to unchoked condition in the gas flow through the vent holes of the primer.[1] After the flow change, the output rate of the igniter gases starts decreasing.

From the high-speed film, we observed that the flame on the surface of the propellant bed was in the form of spots which scattered only in the primer section. It indicates that the flamespreading was confined in that section. Thus in a live charge only the propellant around the primer can be ignited directly by igniter gases. The combustion products of the propellant in that region then ignite the rest of the propellant in the cartridge.

B. <u>Live Propellants</u>

Two kinds of M30 propellant beds were investigated: all granular and granular plus slotted stick as shown in Figure 2. The latter was constructed by replacing the portion of the granular propellant bed located from the boom end to the very forward end of the chamber with slotted stick propellant. A slotted stick propellant bed has long been recognized to have low resistance to a gas flow through it.[2] Thus the main purpose of using the slotted stick propellant was allowing igniter gases and the combustion products of the granular propellant around the primer to quickly reach the forward part of the propelling charge. This should improve flamespreading and thus achieve more uniform ignition along the chamber length.

The granular propellant had a grain size of approximately 15.08 mm (length) by 7.54 mm (diameter) with 7 perforations. The dimensions of the round slotted stick propellant were approximately 152.4 mm (length) by 5.95 mm (diameter). The center hole diameter and the slot width of each stick were 1.59 mm and 0.3 mm, respectively.

The results to be presented in the following emphasize the comparison between the two propellant bed configurations and the temperature effect on the ignition of the propellant, with a focus on the pressure behavior and flamespreading.

1. <u>All Granular Propellant Bed vs. Granular Plus Slotted Stick Propellant Bed</u>

a. <u>All Granular Propellant Bed</u>

Round No. 3 and Round No. 4 were fired at ambient temperature. Their results were to serve as a baseline for comparisons with the data obtained in the subsequent tests. Figures 5 and 6 display the pressure-time curves

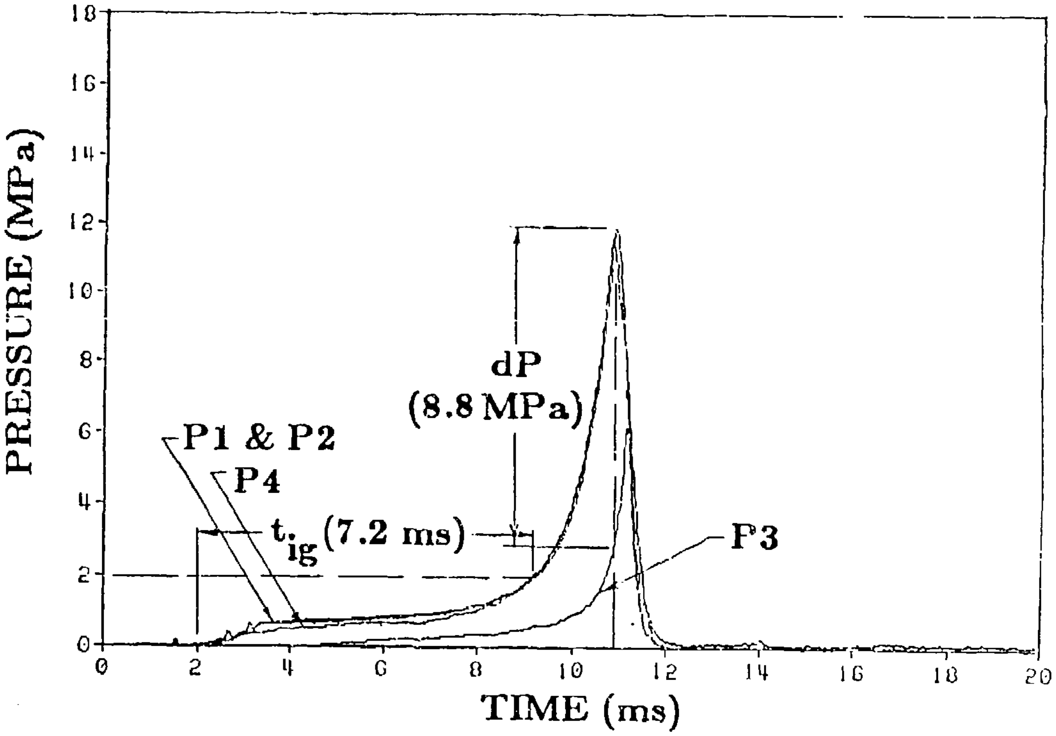


Figure 5. Pressure-Time Data (All Granular Propellant, Fired at Ambient Temperature, Round No. 3)

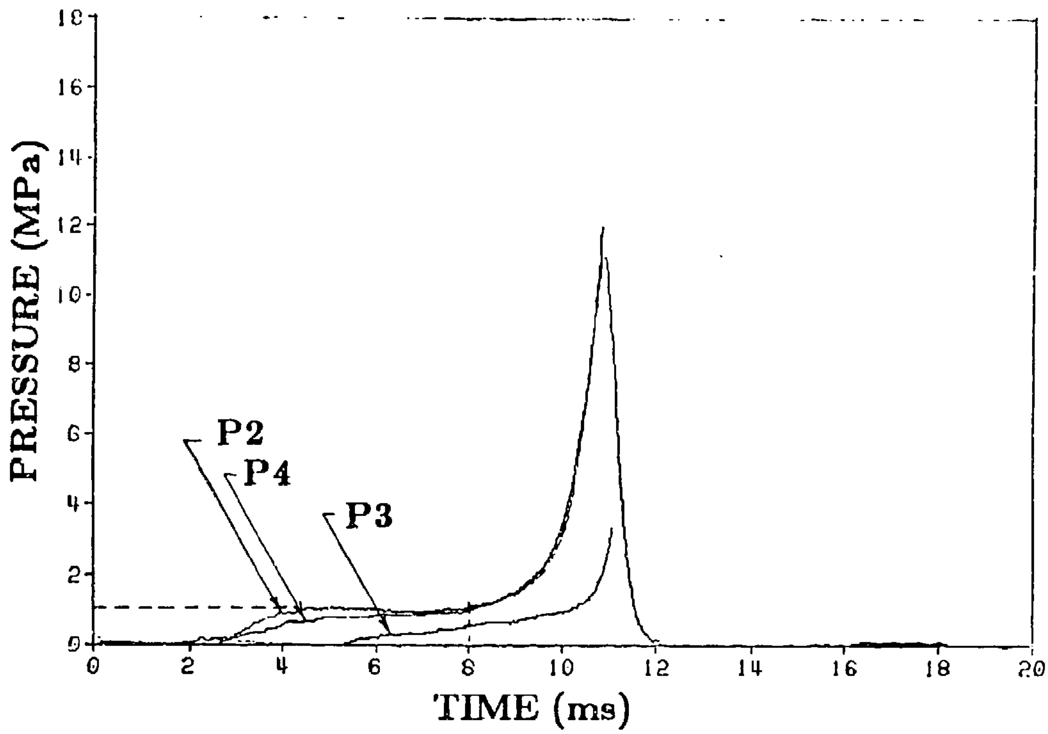
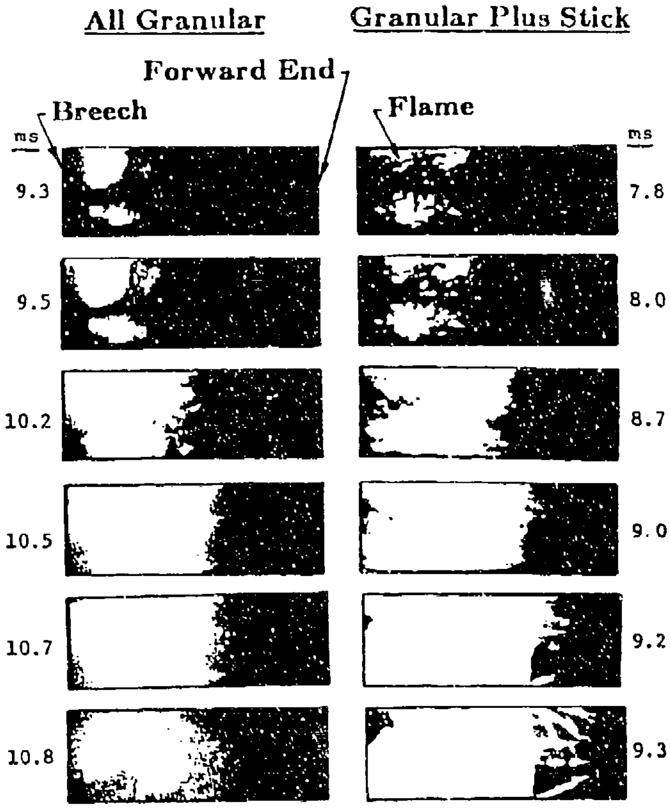


Figure 6. Pressure-Time Data (All Granular Propellant, Fired at Ambient Temperature, Round No. 4)

recorded in the two rounds, showing good reproducibility of the data. In the figures, the pressure peaks occurred within 0.2 ms after the chamber ruptured. In Figure 5, dP is the difference between P_1 and P_3 at the time that the chamber ruptured. t_{ig} denotes the ignition delay which is defined as the time period from the instant that the breech pressure starts to rise to the instant that the pressure reaches 2 MPa. Along the curves, the initial rise of the pressures was solely due to the ignition of the primer. After reaching 0.8 MPa, the pressures stayed level for a few milliseconds before rising again. Based on the results shown in Figure 4 obtained from the inert propellant test, we explain that this was the heat-up period for the propellant surrounding the primer before it started to burn. The pressure 0.8 MPa is higher than the pressure rise (approximately 0.45 MPa in the early period) in the inert propellant charge is believed due to the differences in the loading density and the heat transfer from igniter gases to the grains in the two charges. The second rise of the pressures was truly attributed to the ignition of the propellant. We see that the pressure rise P_3 at the forward end of the chamber lagged the breech pressures P_1 and P_2 and was considerably lower. The implication is that the initial combustion zone was localized near the breech end. This result concurs with the evidence of the flamespreading recorded on the film as shown in the left column of Figure 7. The photographic data show that the rupture of the chamber initiated near the breech end and that at the time of rupture the flame coverage was confined in a region only slightly beyond the mid-point of the chamber length.



Note:
1. Last frames show the instant that the chamber ruptured.
2. The times indicated are the time after application of firing voltage.

Figure 7. Flamespreading in Round No. 4 and Round No. 6

b. Granular Plus Slotted Stick Propellant Bed

Round No. 5 and Round No. 6, see the above table, were packed in the same way except that Round No. 6 had a combustible case inserted around the inner wall of the acrylic chamber. Part of the combustible case was cut off and replaced with a transparent plastic plate to provide a window through which the events occurring inside were able to be visualized. After firing, the fragments of the combustible case gathered on site indicate that only the edge area of some of the fragments had started burning at the time that the chamber ruptured. The pressure data of the two rounds, displayed in Figures 8 and 9, respectively, show little difference with and without a combustible case inserted. However, this should not be interpreted to mean that in gun firings the combustible case has no effects on the interior ballistic performance. In gun firings the combustible case would make a contribution to the total chemical energy in the gun chamber.

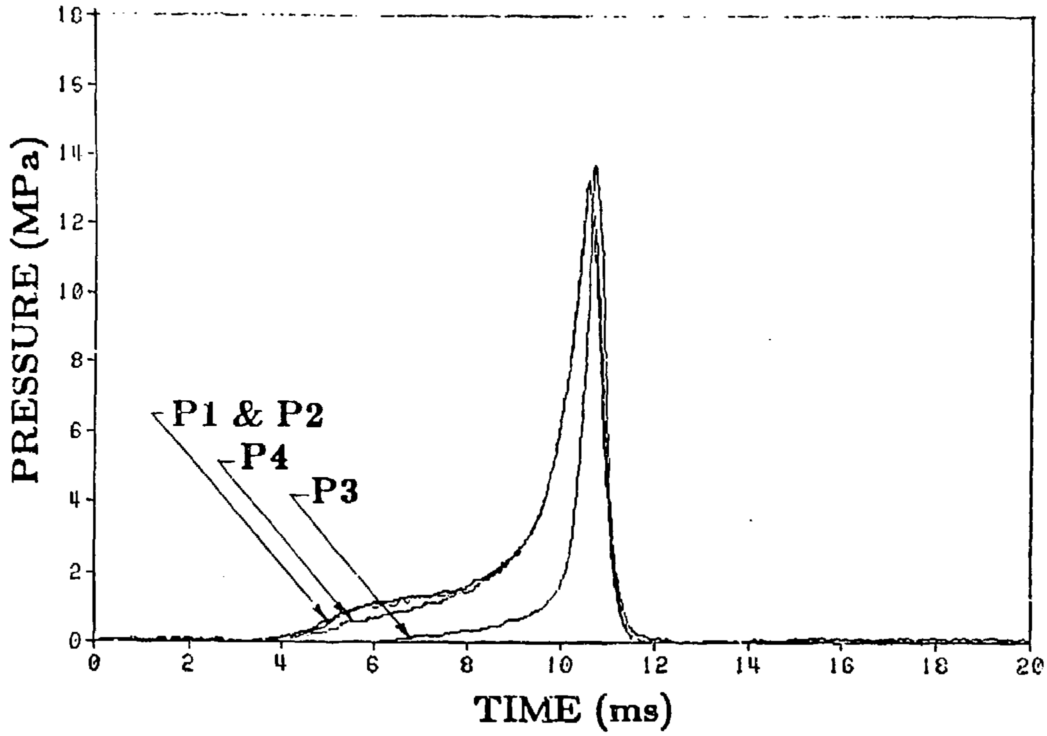


Figure 8. Pressure-Time Data (Granular Plus Slotted Stick Propellant, Fired at Ambient Temperature, Round No. 5)

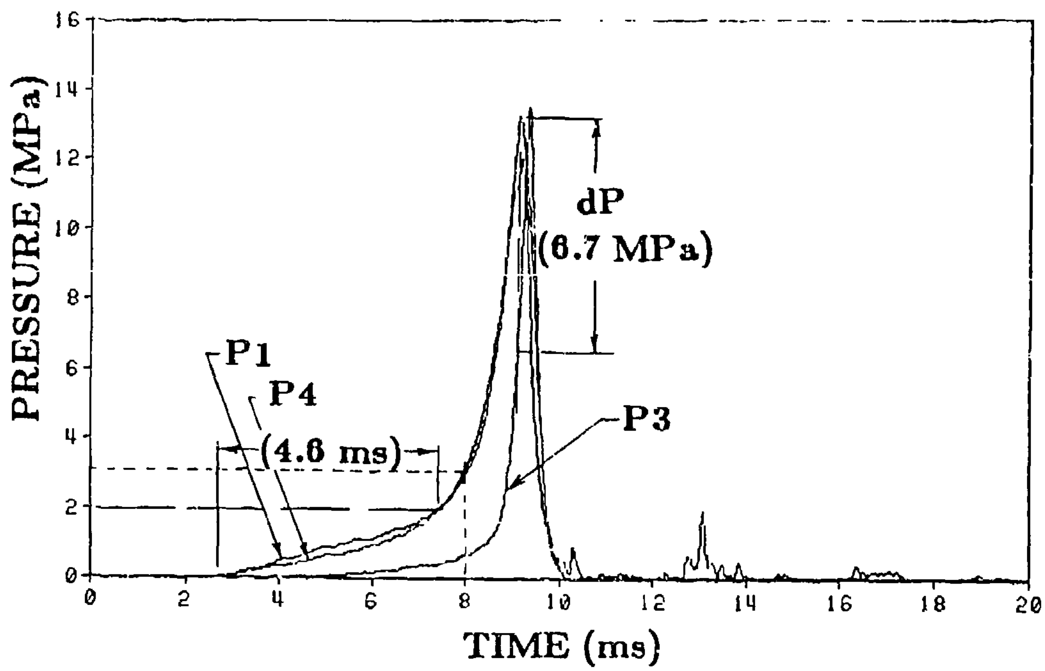


Figure 9. Pressure-Time Data (Granular Plus Slotted Stick Propellant, Fired at Ambient Temperature, with a Combustible Case, Round No. 6)

When comparing Figure 9 with Figure 5, it is seen that the stick propellant bed has achieved a great reduction in ignition delay (4.6 ms compared with 7.2 ms). Also improved is the pressure distribution along the chamber length. This can be seen in Figure 10 which provides a direct comparison of the pressure difference ($dP = P_1 - P_3$) between the breech and the forward end. A smaller dP means a more uniform chamber pressure distribution. The right column of Figure 7 presents the flamespreading in Round No. 6 which was packed with granular and stick propellants. The flame was first seen in the region which corresponds to the mid-section of the vented primer tube. In the early period, the flamespreading is similar to that observed in Round No. 4 with all granular propellant since only the granular propellant located around the igniter was ignited. However, in the later period before the rupture of the chamber, the flame coverage is much larger in the round with a stick propellant bed. This can be clearly identified from Figure 11 which was plotted based on the photographic data given in Figure 7. Figure 11 also shows that the stick propellant bed significantly increases the speed of the flamespreading. For example, at 8 ms

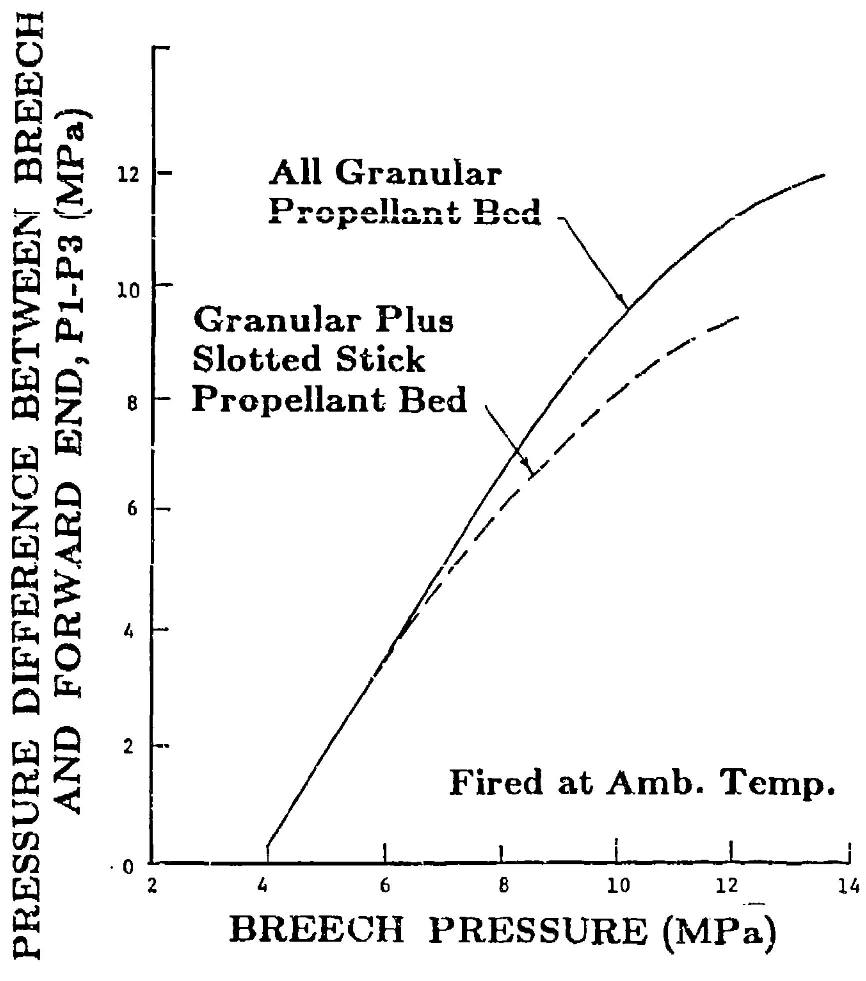


Figure 10. Pressure Difference Between Breech End and Forward End

the flame front reached 240 mm from the breech end for the round packed with the granular plus slotted stick propellant compared with 150 mm for the round packed with all granular propellant. It is interesting to note that the speed of the flame traveling to the breech end for the round packed with the granular plus slotted stick propellant was also greater. This is believed to be related to its faster pressure rise (3 MPa vs. 1 MPa at 8 ms, see Figures 6 and 9). The above data sufficiently evidence the advantage of adopting a stick propellant for improving the flamespreading and the uniformity of the chamber pressure.

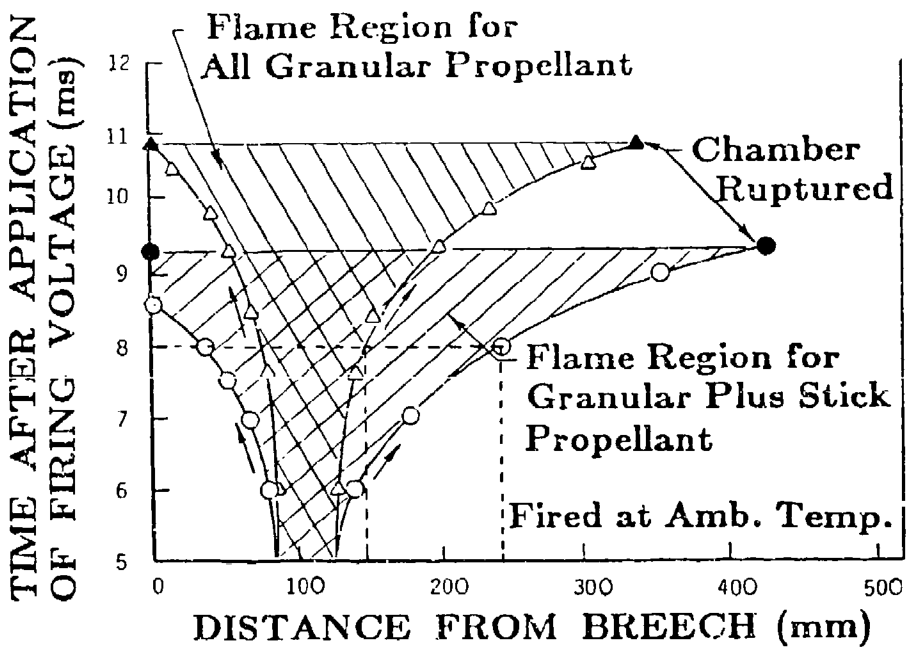


Figure 11. Comparison of Flamespreading (corresponding to Figure 7)

2. Temperature Effect

Before firing, all of the cold rounds had been conditioned in a temperature box set at a prescribed temperature for more than 24 hours. This would ensure a uniform temperature throughout the propellant bed. The rounds were fired within 30 minutes after they were removed from the temperature box. During this setup period, the rounds remained insulated until approximately 30 seconds before firing. The material used for the insulation was an one-inch thick fiberglass blanket. To ensure the cold round remaining at the prescribed temperature, a temperature probe was inserted into the central region of the propellant bed to measure the temperature as a function of time for 45 minutes after the round was removed from the temperature box. The data recorded are given in Table 2, showing that there was no temperature rise during that period.

Table 2. Temperature Measurement in the Propellant Bed After Removed From the Temperature Box at 228°K (-45°C)

Time* (minutes)	3	5	10	15	20	25	30	35	40	45
Temp. (°C)	30**	-39	-41	-43	-44	-45	-45	-45	-45	-45

* Time after the cold round was removed from the temperature box.

** The probe was inserted into the propellant bed 3 minutes after the round was removed from the temperature box. The ambient temperature was 303°K (30°C).

We will examine the temperature effect for the two configurations of propellant beds separately.

a. <u>All Granular Propellant Bed</u>

Round No. 8 was fired at 228°K (-45°C) and its result was given in Figure 12. The resulting ignition delay, t_{ig}, is 11.1 ms which is much longer than

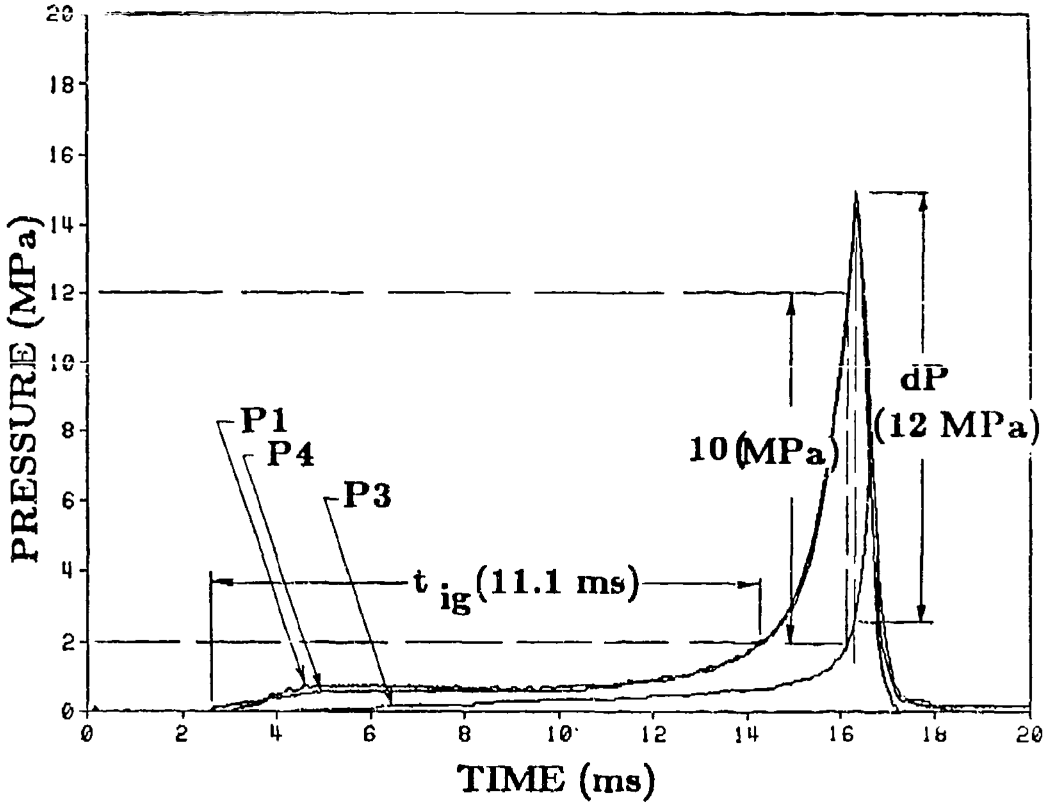


Figure 12. Pressure-Time Data (All Granular Propellant, Fired at 228°K (-45°C), Round No. 8)

7.2 ms indicated in Figure 5 for the ambient temperature round. The reason is simply because it needed more time for the cold propellant to be heated up to its ignition temperature. After the start of rapid rising (around 2 MPa), the pressure profiles shown in Figures 5 and 12 appear to be similar. A close comparison of them, however, reveals that at the same pressure level, say 12 MPa (at which the chamber of the ambient temperature round ruptured), the pressure difference between the breech and the forward end in the cold round is larger (10 MPa compared with 8.8 MPa). In concurrence with this difference, the flamespreading observed in the cold round was more confined to the region near the breech end than it was in the ambient temperature round.

b. Granular Plus Slotted Stick Propellant Bed

Fired at 228°K (-45°C)

Both rounds No. 7 and No. 9 were packed in the same configuration with a combustible case and fired at 228°K (-45°C). As shown in Figure 13 and Figure 14, these two rounds do not have the same ignition delay (14.1 ms compared with 11.8 ms). The discrepancy may be attributed to a variation in

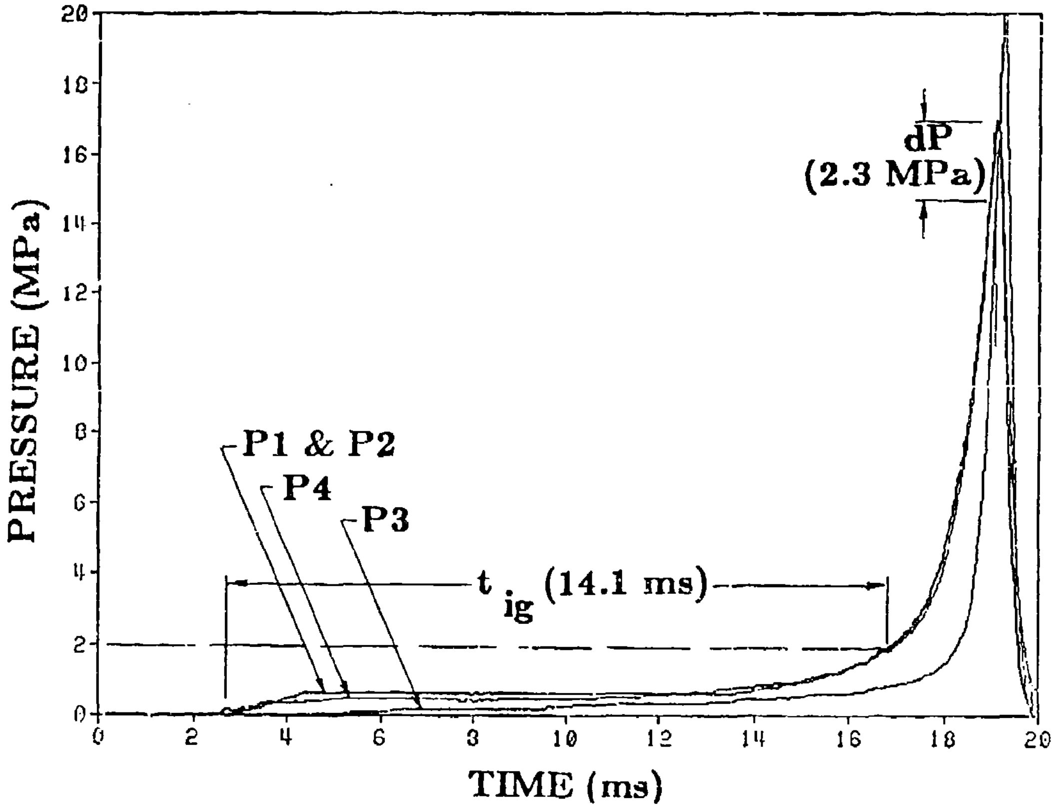


Figure 13. Pressure-Time Data (Granular Plus Slotted Stick Propellant, Fired at 228°K (-45°C), Round No. 7)

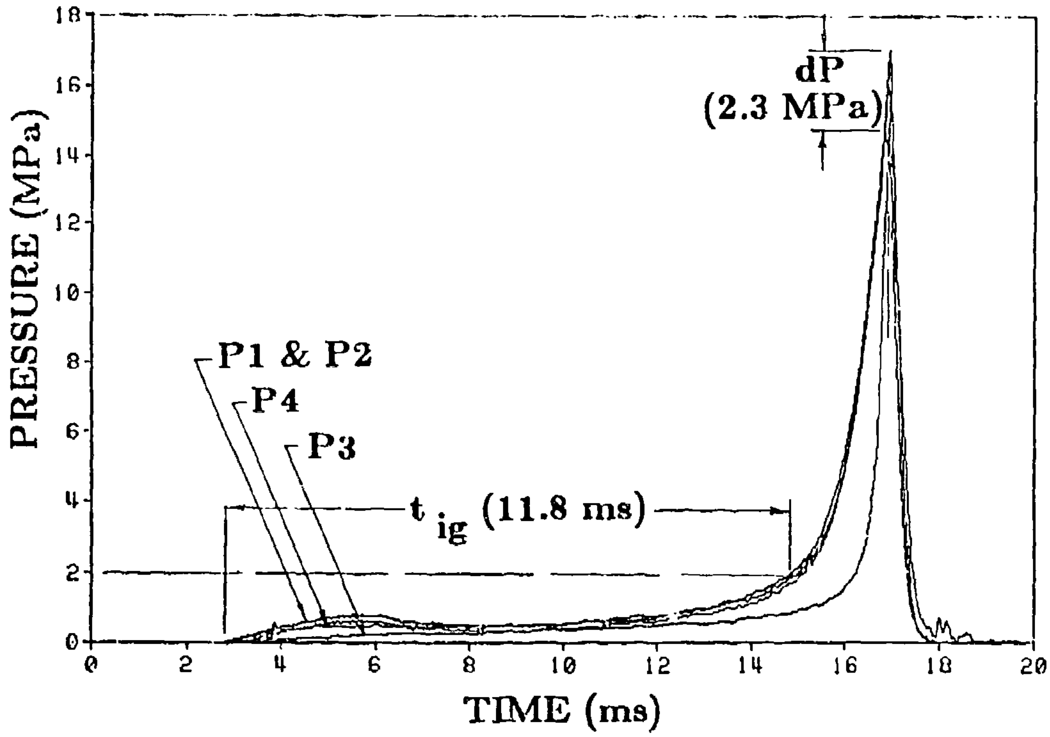


Figure 14. Pressure-Time Data (Granular Plus Slotted Stick Propellant, Fired at 228°K (-45°C), Round No. 9)

the rate of output of igniter gases which could be sensitive to a temperature change. Nevertheless, their pressure behaviors are alike before the rupture of the chamber. When compared with the pressure profiles shown in Figure 12 for the round without slotted stick propellant, the pressure difference between the two chamber ends at the time of rupturing is much smaller for rounds No. 7 and No. 9 (2.3 MPa compared with 10 MPa). The indication is that the chamber pressure in the rounds packed with slotted stick propellant is more uniform, which is the same as the previous result observed in the ambient temperature rounds.

When considering rounds packed with slotted stick propellant, a comparison between the cold round (Figure 14) and the ambient temperature round (Figure 9) shows no significant differences in their pressure rises though the ignition delay for the cold rounds is longer. The peak pressure recorded in the cold round appears to be higher than that in the round fired at ambient temperature. This seems to be because the chamber at a lower temperature can withstand a higher pressure limit. In general, a chamber can also withstand a higher pressure limit at a higher pressurization rate. Such a possibility does not apply to the present case since the pressurization rate in the round fired at ambient temperature is actually higher as compared in Figure 15.

The photographic data show that both the cold and ambient temperature rounds have similar flamespreading after the ignition of propellant has started.

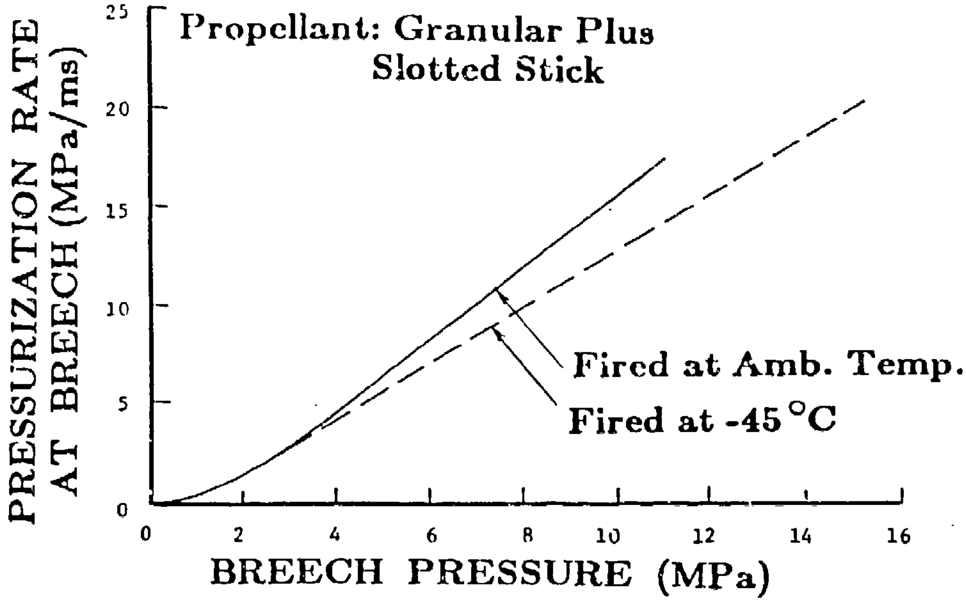


Figure 15. Pressurization Rate at Breech

Fired at 241°K (-32°C)

Rounds No. 10 and No. 11, both with a combustible case, were conditioned to 241°K (-32°C). Their pressure data recorded are given in Figures 16 and 17, respectively. As in the case of 228°K (-45°C), the ignition delays in the two rounds are not equal (12.5 ms vs. 6.4 ms). However, their pressure rises in the range above 2 MPa are very much the same though one of the peak pressures is higher. A comparison between Figure 17 for the cold round and Figure 8 for the ambient temperature round shows no significant differences in their pressure rises after the propellant was ignited (i.e., above 2 MPa). The high-speed films also show no significant differences in flamespreading when the round was conditioned from ambient temperature to 241°K (-32°C).

Based on the comparisons made in Subsections B.2.a and B.2.b, it is concluded that the chamber pressure distribution and flamespreading in the rounds packed with slotted stick propellant are less sensitive to a temperature change from ambient to 228°K (-45°C) than all granular charges.

C. Projectile Displacement

The projectile displacement recorded in various rounds ranges from 20 mm to 40 mm. The variation in the displacement in the early stage is a strong function of the pressurization rate in the chamber. A fast pressurization rate results in a smaller displacement because of a shorter accelerating time

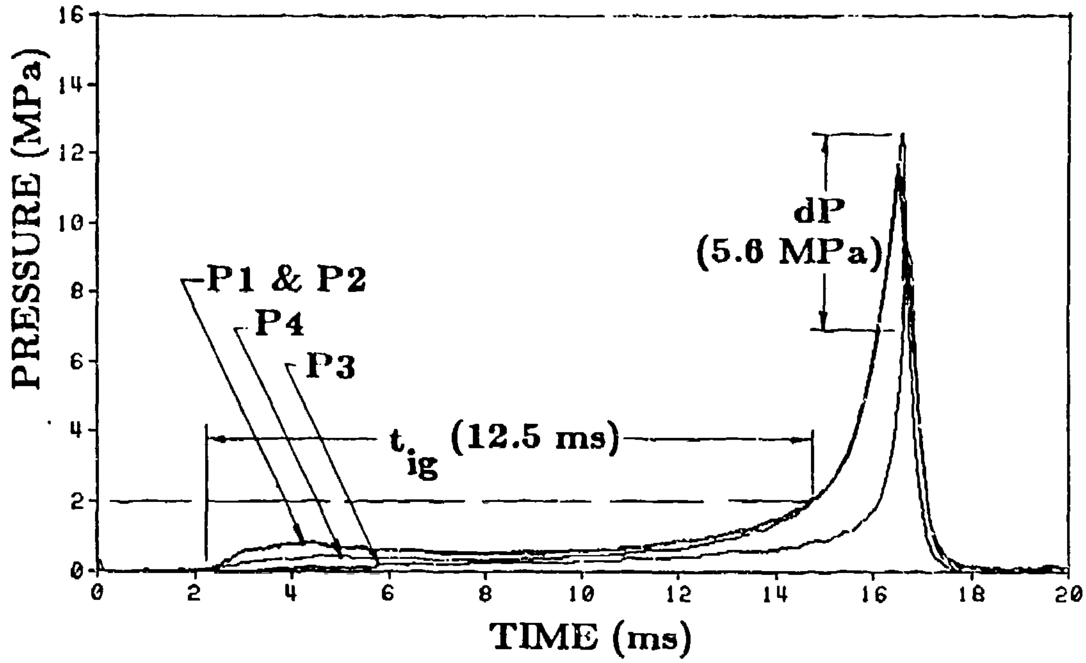


Figure 16. Pressure-Time Data (Granular Plus Slotted Stick Propellant, Fired at 241°K (-32°C), Round No. 10)

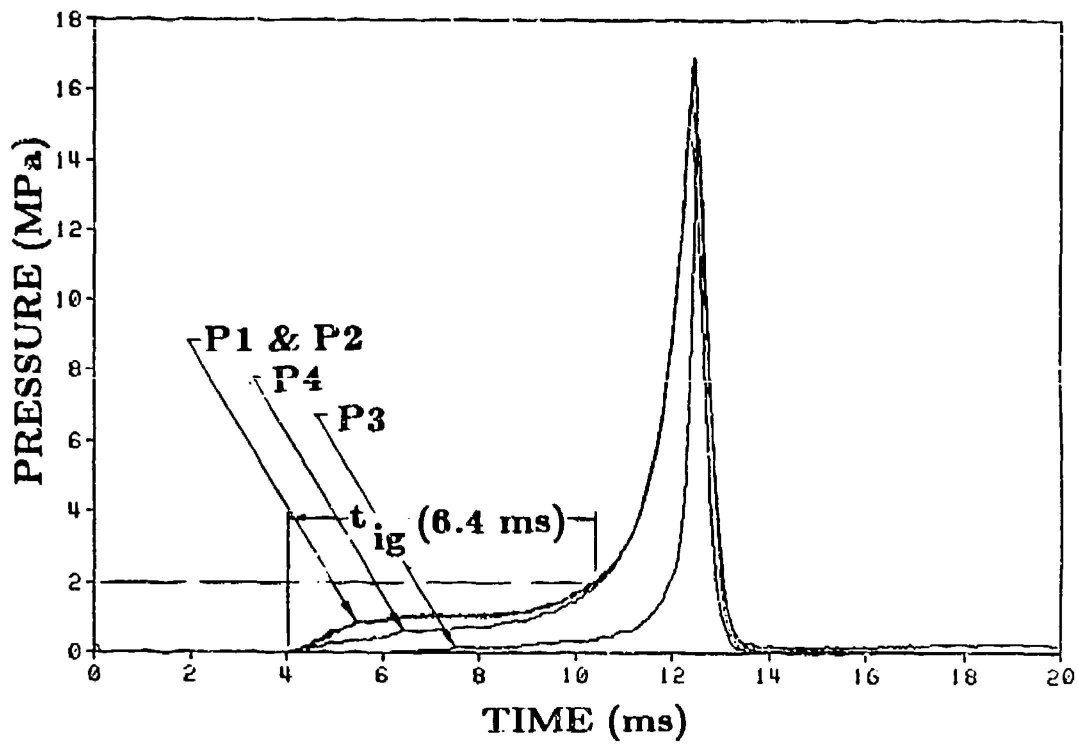


Figure 17. Pressure-Time Data (Granular Plus Slotted Stick Propellant, Fired at 241°K (-32°C), Round No. 11)

for the projectile. As a typical case, Figure 18 presents the result of Round No. 9. For the convenience of reference, the pressure P_4 (which was close to the boom end of the projectile) shown in Figure 14 was re-plotted in Figure 18. We see that the projectile started to move 2.3 ms after the initial rise of the breech pressure. After a small movement, the projectile virtually stopped until the breech pressure started rising again. The intermittence is due to the long ignition delay appearing on the pressure curve. After the chamber rupture which occurred at 16.9 ms, the projectile continuously moved additional 35 mm. This additional movement seems to be a result of the inertia forces of the moving projectile and propellant grains.

As a note, we also examined the condition of the obturators post firing. Such an examination will help us to detect an early failure in an obturator occurring during its engraving period. In the present investigation, one of the obturators fired at 241°K (-32°C) and all at 228°K (-45°C) were found to have severe cracks in the circumferential direction. In Rounds No. 8 and No. 9, in particular, large pieces of the obturators separated from the main body. This might cause inadequate sealing around the projectile while moving down the gun barrel. No such cracks were seen in the rounds fired at ambient temperature.

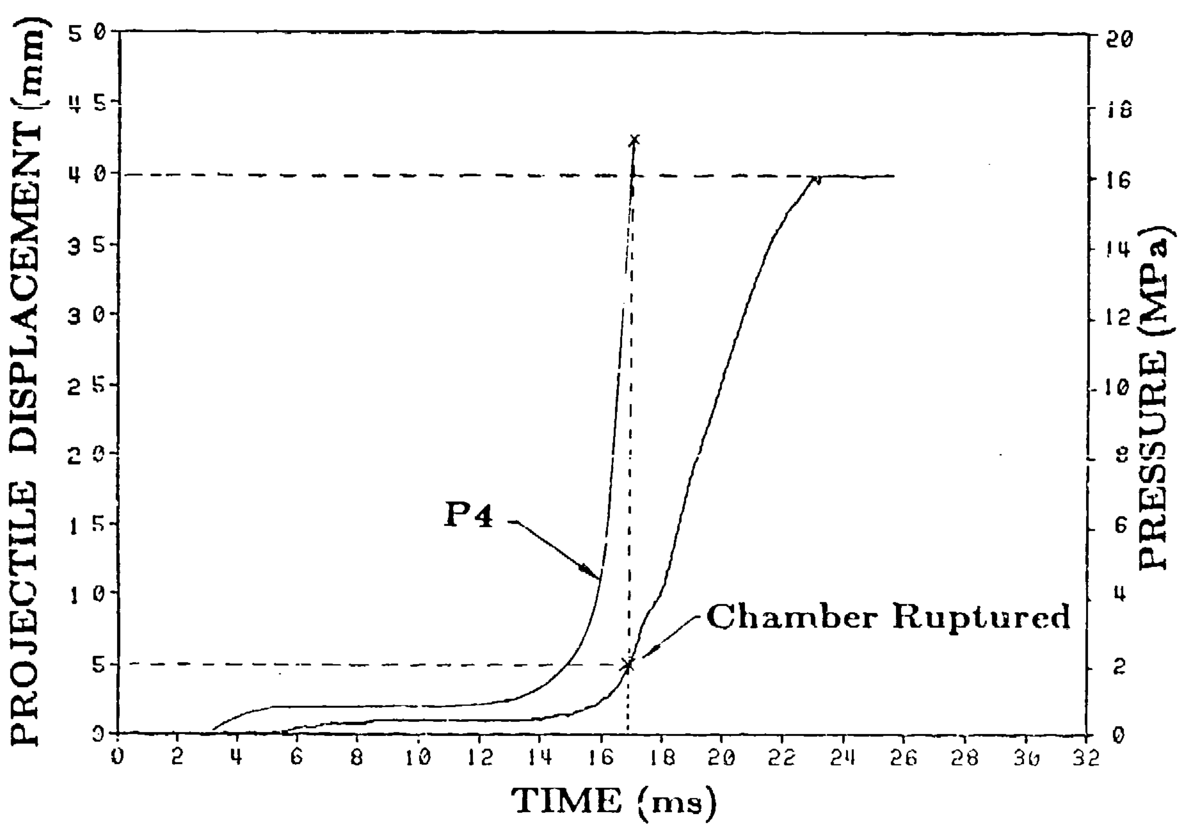


Figure 18. Projectile Displacement (Granular Plus Slotted Stick Propellant, Fired at 228°K (-45°C), Round No. 9)

Figure 19. Cracked Obturator After Firing

IV. SUMMARY AND CONCLUSIONS

The program has proceeded successfully to investigate the early ignition processes occurring in the XM859 HEAT-MP cartridge. In the processes, the functioning of the igniter, the pressure behavior, and the flamespreading in the cartridge have been characterized.

In this program, eleven rounds were fired using a 120-mm gun simulator, including inert propellant and live charges at three temperature conditions (ambient, 241°K, and 228°K). The results from the rounds packed with inert propellant show that the chamber pressurization due to ignition of an primer alone is in the order of 0.5 MPa. The flamespreading from the igniter ignition was confined in a small region around the igniter, suggesting that in a live charge only the propellant in that region would be ignited directly by igniter gases. In the rounds packed with all granular live M30 propellant, the chamber pressure and flamespreading were quite localized in the section near the breech. No noticeable difference was observed in the results with and without a combustible case since the case might have not started burning at the instant the chamber ruptured. When the forward section of the granular charge was replaced with a slotted stick propellant bed, the ignition delay was substantially reduced. The flamespreading and the uniformity of chamber pressure were also improved.

When the rounds were conditioned from ambient temperature to 241°K (-32°C) and 228°K (-45°C), the ignition delay became much longer, by a factor of two in some cases. However, in the rounds packed with slotted stick propellant the pattern of pressure rise and flamespreading at the low pressure region before the rupture of the chamber exhibited no unusual changes from ambient temperature to cold.

There was no sign of forming pressure waves at 17 MPa or less which could lead to catastrophic overpressurization in cold temperature environments due to poor ignition and flamespreading.

The obturators on one of the rounds conditioned to 241°K (-32°C) and all of the rounds conditioned to 228°K (-45°C) were found to have severe cracks in the circumferential direction.

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REFERENCES

1. L.M. Chang and J.J. Rocchio,"Early Phase Interior Ballistic Cycle Studies in a 105-mm Tank Gun Simulator," Proceedings of the 8th International Symposium on Ballistics, pp. I-13 - I-24, Oct 1984.

2. A.W. Horst and T.C. Minor,"Theoretical and Experimental Investigation of Flamespreading Process in Combustible-cased, Stick Propellant Charges," Proceedings of the 8th International Symposium on Ballistics, pp. IB-21 - IB-31, Oct 1984.

3. Thomas C. Minor, "Mitigation of Ignition-Induced, Two-Phase Flow Dynamics in Guns Through the Use of Stick Propellant," ARBRL-TR-02508, Ballistic Research Laboratory, USA ARRADCOM, Aug 1983.

4. Thomas C. Minor and Albert W. Horst, "Ignition Phenomena in Developmental, Stick Propellant, Combustible-Cased, 155-mm, M203E2 Propellant Charges," ARBRL-TR-02568, Ballistic Research Laboratory, USA ARRADCOM, Jul 1984.

5. Albert W. Horst, Frederick W. Robbins, and Paul S. Gough, "Multidimensional, Multiphase Flow Analysis of Flamespreading in a Stick Propellant Charge," ARBRL-MR-03372, Ballistic Research Laboratory, USA ARRADCOM, Aug 1984.

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